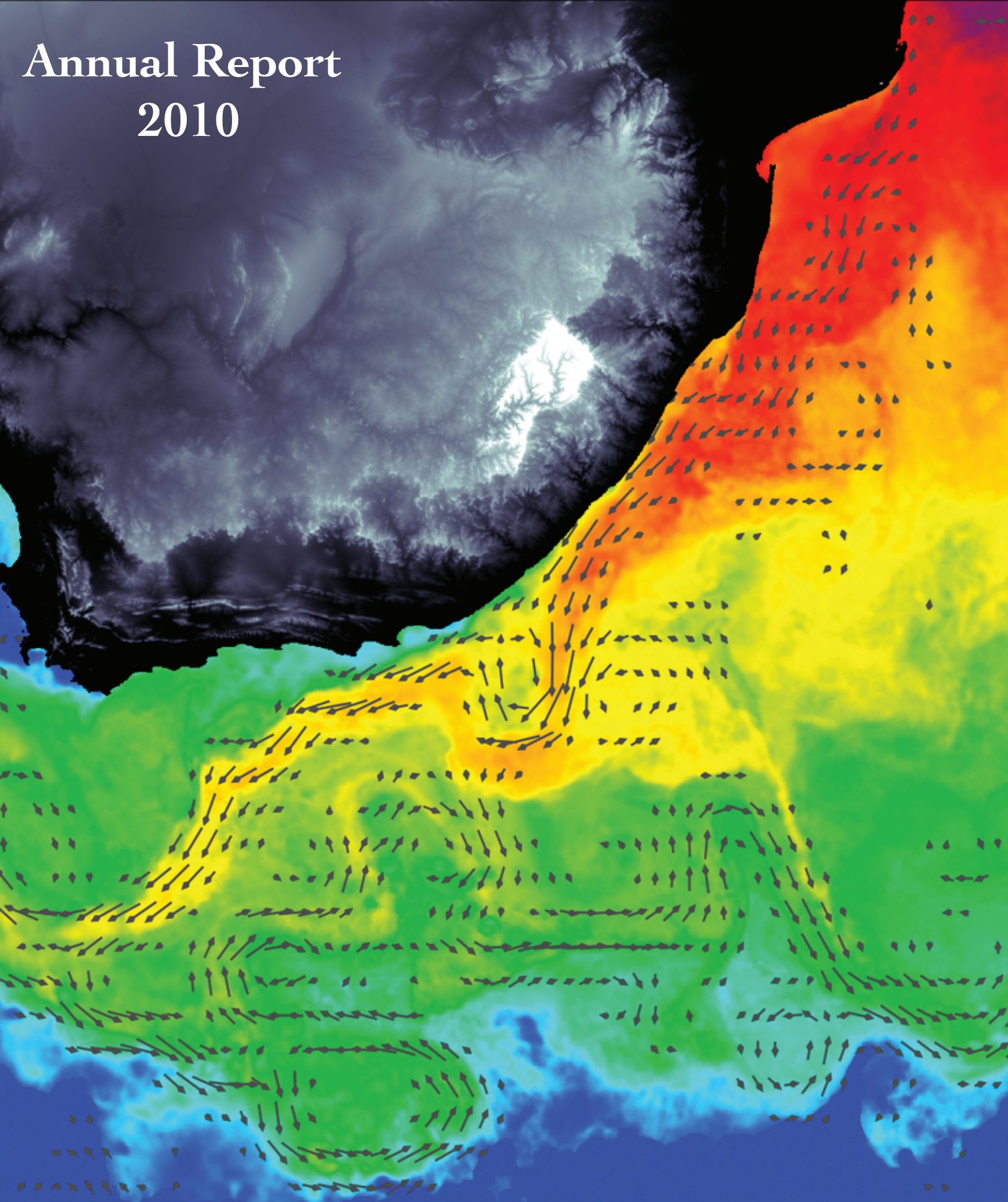


Annual Report 2010



Nansen-Tutu Centre for
Marine Environmental Research

Cape Town, South Africa
affiliated with the University of Cape Town

2010 – REPORT FROM THE BOARD

INAUGURATION

The Nansen-Tutu Centre for Marine Environmental Research was conceived through research collaboration between scientists at the Nansen Centre in Bergen and their colleagues in South Africa. The Centre rests on a joint venture agreement that was signed by its patron, Archbishop Emeritus Desmond Tutu, and representatives of its sponsors from Norway, South Africa and US in May 2010 (<http://www.neresc.no/sites/www.neresc.no/files/NTC-Joint-Venture-Agreement.pdf>). To launch the scientific activities of the Nansen-Tutu Centre, a Scientific Symposium was held at the Westin Grand Arabella Quays in Cape Town on 7-9 December 2010. The conference proceedings provides a record of the symposium and will be available in 2011.

VISION

The vision of the Nansen-Tutu Centre for Marine Environmental Research is to serve Africa through advancing knowledge of the marine environment and climate system in the spirit of Nobel Peace Laureates Desmond Tutu and Fridtjof Nansen.

RESEARCH ACTIVITIES

The aim of the Centre is to improve the capacity to observe, understand and predict marine ecosystem variability on timescales from days to decades in support of scientific and

societal needs including fisheries, coastal management, maritime security, recreation and tourism.

To this end, one of the core activities at the Centre will focus on education and exchange of young researchers and students from different cultures and countries through the Nansen-Tutu Scholarship Program.

The approach adopted by the Nansen-Tutu Centre is to develop and implement state-of-the-art ocean observing and modelling systems related to the unique position of South Africa at the meeting place of the cool Benguela Current adjacent to the warm Agulhas Current, and close proximity to the Southern Ocean.

The focus is to study the variability of these current and ocean systems on a variety of time-scales in relation to their mutual local and regional interaction with the atmosphere and land, rainfall patterns, and other weather patterns vital to society. In developing and implementing the technology and expertise to observe and model ocean and climate variability, the skills needed in southern Africa will be updated and expanded through priority research and development activities.

ORGANIZATION

The Nansen-Tutu Centre is a non-profit research institute hosted at the Marine Research Institute and the Department of Oceanography at the University of Cape Town. The administrative and legal responsibilities reside with the University of Cape Town. It is a joint venture agreement between the founding partners: Marine Research Institute (MA-RE)/ Department of Oceanography, University of Cape Town, Cape Town, South Africa, African Centre for Climate and Earth

System Studies (ACCESS), Council for Scientific and Industrial Research (CSIR), South Africa, the Nansen Environmental & Remote Sensing Centre (NERSC), Bergen, Norway, Institute of Marine Research (IMR), Bergen, Norway, Geophysical Institute, University of Bergen, Bergen, Norway, and Princeton University, USA.

The Nansen-Tutu Centre conducts marine environmental research, with a particular focus on southern Africa and research and development underpinning operational oceanography. Funding for projects is applied for externally. Potential funding agencies include South-African and Norwegian bodies, bilateral funding agreements, the European Union's Framework Programmes, space agencies, industry and private sponsors.

STAFF

Since its inception in May 2010 and up to December 2010, the Nansen-Tutu Centre comprises 12 persons, including seconded researchers from the Nansen-Tutu Centres founding partners, namely the Marine Research Institute and the Department of Oceanography at the University of Cape Town, the African Centre for Earth System Science at the Council for Scientific and Industrial Research, Princeton University, the Institute for Marine Research, the University of Bergen and the Nansen Environmental and Remote Sensing Center.

SCIENTIFIC PRODUCTION

From May 2010 to December 2010, five articles were published in international referee journals, one article in conference proceedings, one progress report, as well as one popular science article – totaling eight publications.

After completing their studies

COVER IMAGE: Sea surface temperatures from SEVIRI overlaid with geostrophic currents derived from altimetry measurements of the sea level.
Courtesy: Marjolaine Rouault (CSIR - Earth Observation).

with supervision from Nansen-Tutu Centre senior scientists two PhD students graduated at the University of Cape Town this year:

- Dr. Bjorn Backeberg:
Modelling the mesoscale variability in the greater Agulhas Current System using a Hybrid Coordinate Ocean Model. Doctoral Thesis, Department of Oceanography, University of Cape Town, South Africa. Supervisors at the Nansen-Tutu Centre: J. A. Johannessen, C. Reason.
- Dr. Jennifer Veitch:
Equilibrium dynamics of the Benguela system: a numerical modelling approach. Doctoral Thesis, Department of Oceanography, University of Cape Town, South Africa. Supervisors at the Nansen-Tutu Centre: F. Shillington.

INTERNATIONAL ACTIVITIES

The Nansen-Tutu Center opening symposium was hosted jointly with the Centre for High Performance Computing annual meeting, and was held at the Westin Grand hotel in Cape Town from 7-9 December 2010. Ninety participants including students, from both national and international institutes both in Africa and Europe attended. Keynote presentations on the southern African regional oceanography (including the Southern Ocean), societal impacts, ecosystem challenges, and operational oceanography were given by invited local and international experts.

The Nansen-Tutu Centre is a member of the Nansen Group which consist of Nansen Centers in Bergen, Norway – St. Petersburg, Russia – Cochin, India and Beijing, China, lead by

Prof. Ola M. Johannessen.

FINANCIAL SITUATION

The Nansen-Tutu Centre is a non-profit joint venture agreement hosted at the Department of Oceanography at the University of Cape Town. For the financial year 2010, the Nansen Tutu Centre received direct funding from the Nansen Environmental and Remote Sensing Center, the Institute for Marine Research, the Nansen Scientific Society, the University of Bergen and the Applied Centre for Climate and Earth System Science, amounting to 870 000 ZAR (623 000 NOK). The University of Cape Town provides in kind contributions in the form of infrastructure and administrative support for the centre.

PROSPECTS FOR 2011

- Hire PhD and master students as well as Post-doctoral research fellow.
- Establish service level agreement with MyOcean.
- African Operational Oceanography workshop (June 2011).
- Cooperation with ICEMASA and other programmes at UCT.

Cape Town, October 2011

Prof. J.G. Field, Ma-Re Institute (Chair)

Prof. O.M. Johannessen, NERSC (Co-Chair)

Res. Dir. E. Svendsen, IMR (Co-Chair)

Dr N. Sweijd, ACCESS/CSIR

Prof. P. M. Haugan, Geophysical Institute, University of Bergen

Prof. G. Philander, Princeton University.



NANSEN-TUTU CENTRE
MARINE ENVIRONMENTAL RESEARCH

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Mr. Emlyn Balarin, Marine Research Institute, University of Cape Town

EXECUTIVE SUMMARY

FRANK SHILLINGTON,
JOHNNY JOHANNESSEN AND
BJORN BACKEBERG

Following the inauguration of the Nansen-Tutu Centre with the signing of the collaboration agreement by Nobel Peace Prize Laureate, Emeritus Archbishop Desmond Tutu, in May 2010, much of the centre's activities revolved around organising the scientific opening symposium. This was held in Cape Town in December 2010, in conjunction with the "OceanSAfrica" operational oceanography initiative around southern Africa. The "OceanSAfrica" project aims to serve as a vehicle for developing an integrated, multi-institutional strategic capability in Africa for the development of sustainable marine science underpinning operational activities. The opening symposium highlighted the Nansen-Tutu Centre's plans, emphasizing that the overarching research and operational goals of the Nansen-Tutu Centre and OceanSAfrica are well aligned.

This joint meeting and symposium was hosted by the Centre for High Performance Computing, and was held at the Westin Grand hotel in Cape Town. Ninety participants including students, from both national and international institutes attended the meeting which was held from 7-9 December 2010. Keynote presentations on the southern African regional oceanography (including the Southern Ocean), societal impacts, ecosystem challenges, and operational oceanography were given by invited local and international experts. The symposium consisted of three main sessions:

The Nansen-Tutu Scientific Opening

Speakers in this session presented the priority research activities related to the marine environment of the oceans around southern Africa: the Indian Ocean to the east, the South Atlantic to the west and

the Southern Ocean. Each area has distinct regional marine characteristics. The aim was to outline outstanding research questions, and in active open discussions, to formulate cohesive research challenges and scientific strategies.

OceanSAfrica Operational Oceanography & High Performance Computing

The focus of this session was on developing the highly technical requirements and plans needed to fully utilize the parallel computing resources at the national South Africa Centre for High Performance Computing, hosted in Rosebank Cape Town. It became clear that emerging Very Large Data Base capabilities are needed to archive, interrogate, analyze, visualize and disseminate highly refined end products from the large volumes of observed and modeled geo-spatial data.

Student Posters

Post-graduate students were encouraged to present posters displaying their research results. Mr Issufo Halo from Mozambique, received a cash prize for the best poster presentation on the application of a regional ocean model for the Mozambique Channel.

The outcome of the symposium has been published in a conference proceedings, available at <http://www.nersc.no/sites/www.nersc.no/files/NTC-Opening-Symposium-Proceedings.pdf>. The document gives an overview of the research interests and challenges targeted by the Nansen-Tutu Centre. They ranged from descriptions of global ocean modeling projects like "MyOcean" and "Mercator", to ocean-atmosphere interactions, regional ocean modeling, the

effects of climate variability on biodiversity and fisheries, and reviews of aspects of the

Benguela Current, Agulhas Current, and Southern Ocean marine environments and ecosystems. Technical topics concerning new methods of making routine *in situ* ocean observations, satellite remote sensing, database management and data assimilation into models were also addressed. All in all, the topics covered in the symposium proceeding are essential to advance the understanding of the regional marine environment and develop an observing and forecasting system for the state of the oceans around southern Africa, in much the same way that we today have routine access to weather reports and forecasts from the weather service.

OCEAN CLIMATE VARIABILITY AND IMPACTS ON SOUTHERN AFRICAN RAINFALL

MATHIEU ROUAULT AND
CHRIS REASON

Recent work has confirmed the role of El Niño and La Niña (also referred to as the El Niño Southern Oscillation, ENSO) as the major driver of South African inter-annual climate variability and its impact on rainfall, vegetation and stream flows. However, the relationship between ENSO and rainfall is not linear (see Figure 1). For instance, the strength of El Niño is not proportional to the spatial extension and intensity of drought in Southern Africa. Other modes of climate variability such as the Madden Julian Oscillation (MJO) and the Antarctic Annular Oscillation (AAO) also have impacts and these have been

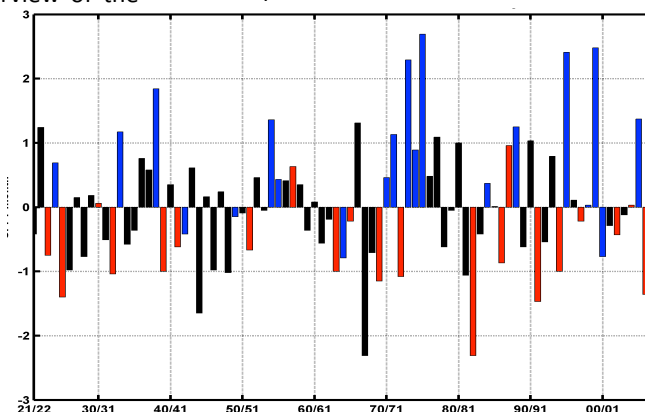


Figure 1: Austral summer (DJF) Standardised Precipitation Index from 1921/1922 to 2007/2008. El Niño year in red, La Niña in blue. Positive value is wetter than normal. Negative is dryer. Value between 1 and -1 occur 66 % of the time above or below one 17 % respectively.

documented. The strongest correlations are found between South African rainfall and ENSO (Nino3.4 index) in summer, mostly between December and February.

Weaker negative correlations are also found in November, March and April for summer rainfall. A positive correlation between winter rainfall in South Africa's winter rainfall region and ENSO has emerged. A positive correlation between AAO and rainfall in summer for the summer rainfall region is an artefact and merely reflects the effect of ENSO. Correlations between the QBO and subtropical Indian Ocean or South African rainfall are very weak and again, merely reflect the impact of ENSO on those features. At the decadal scale, there is no correlation between Sunspot Numbers on South African rainfall. A wavelet analysis of 80 years of South African rainfall data does not indicate any coherent periodicity for the whole period. Sporadic periodicity in the 2-3 years range and 4-5 years range period indicates the relationship with ENSO that has exhibited the same, often interrupted, periodicity over the last 100 years. A 20 year pseudo-periodicity is only found from 1940 to 1980. This lack of periodicity is a major obstacle for seasonal or decadal prediction of rainfall based on statistics only.

Important advances in climatology at the inter-annual and intra-seasonal time scales and at the catchment scale have been made as a result of a thorough analysis of the unique South African rainfall database that contains quality-controlled data from about 5000 daily rainfall stations covering the period 1950 to 2000. This has led to a better understanding of the sub-seasonal variability of convection and rainfall over South Africa during summer. The intra-seasonal timescale has been studied with special emphasis on the 30-60 day variability related to the Madden Julian Oscillation (MJO). Studies have also been extended to the shorter synoptic time scale, where the focus has been on recurrent regimes of daily convective anomalies. This is a very important

result as the MJO is the dominant mode of atmospheric variability in the tropics at intra-seasonal timescales, just as ENSO is the dominant signal at the inter-annual timescale. The MJO basically consists of a slow eastward propagation of large-scale convective clusters along the equator, from the Indian Ocean to the Maritime Continent and then to the Western Pacific basin. The time taken by the MJO to rejuvenate over the Indian Ocean is typically between 40 and 45 days, but it more generally fluctuates between 30 and 60 days. Anomalous daily convective activity over the region has been separated into different regimes or "attractors". The variability in the frequency of these daily regimes from one year to another seems to be related to large-scale signals in the ocean-atmosphere system, among which is the ENSO signal. Thus, for instance, ENSO modulates the frequency of 4 of the 7 identified regimes in a manner that projects onto the seasonal averages.

ON COASTAL OCEANIC CLIMATE CHANGE AROUND SOUTH AFRICA

MATHIEU ROUAULT

In Rouault et al (2010), changes and fluctuations in sea surface temperature (SST) around the South African coast are analysed at a monthly timescale from 1985 to 2007 (see Figure 2). There is a statistically significant negative trend of up to 0.5°C per decade in the southern Benguela from January to August, and a cooling trend of lesser magnitude along the South Coast and in the Port Elizabeth/Port Alfred region from May to August. The cooling is due to an increase in upwelling-favourable southeasterly and easterly winds. There is a positive trend in SST of up to 0.55°C per decade in most parts of the Agulhas Current system during all

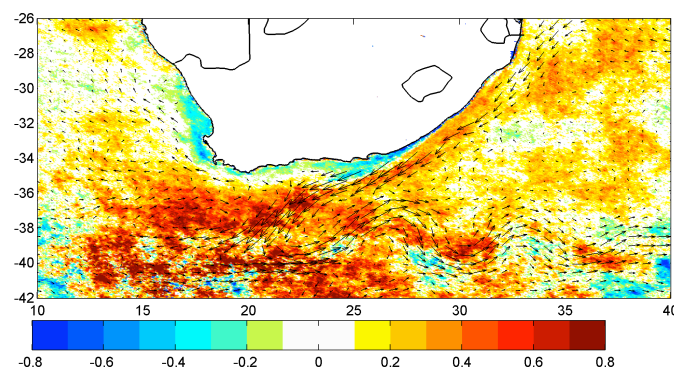


Figure 2: Change in sea surface temperature from 1985 to 2007 in °C per 10-year using 4 km resolution AVHRR only. Superimposed is the altimetry derived 1993-2009 mean geostrophic current.

months of the year except for Kwazulu-Natal, where warming is in summer. The warming was attributed to an intensification of the Agulhas Current in response to a poleward shift of westerly winds and an increase in trade winds in the South Indian Ocean at relevant latitudes. This intensification of the Agulhas Current could also have contributed to the coastal cooling in the Port Alfred dynamic upwelling region. The *El Niño* Southern Oscillation (ENSO) is significantly positively correlated at a 95% level with the southern Benguela and South Coast from February to May, and negatively correlated with the Agulhas Current system south of 36°S. The correlation with the Antarctic Annular Oscillation is weaker and less coherent. *El Niño* suppresses upwelling along the coast, whereas *La Niña* increases it. Although there does not seem to be a linear relationship between the strength of the ENSO and the magnitude of coastal SST perturbation, *El Niño* and *La Niña* appear to be linked to major warm and cool events at a seasonal scale in summer in the southern Benguela and along the South Coast.

IMPORTANCE OF THE EQUATORIAL INDIAN OCEAN FOR MOZAMBIQUE CHANNEL EDDIES

BJORN BACKEBERG AND CHRIS REASON

Eddies with spatial scales of approximately 300-350 km dominate the flow regime in the Mozambique Channel. Altimetry observations indicate that these

eddies propagate southward at approximately $3\text{--}6\text{ km.d}^{-1}$, and most modern eddy-resolving models are able to simulate their dimensions and southward drift reasonably well.

It has been suggested that westward propagating Rossby waves, related to wind anomalies associated with the Indian Ocean Dipole cycle, affect the intensity of the mesoscale activity and the frequency of eddy occurrences in the channel. Furthermore, mesoscale eddies originating in the Mozambique Channel have been implicated in generating disturbances in the Agulhas Current that ultimately affect the Indo-Atlantic inter-ocean exchange south of Africa by triggering the shedding of Agulhas rings from the retroflexion.

The Agulhas leakage is considered to play an important role in maintaining the Atlantic Ocean meridional overturning circulation and climate. Therefore the

thermohaline circulation, and hence climate variations, may be connected to large-scale modes of variability in the Indian Ocean, such as the Indian Ocean Dipole and El Nino Southern Oscillation.

To date, the eddy formation mechanism in the Mozambique Channel is not well explored. Observations from a current meter mooring array indicate that Mozambique Channel eddies form near the narrows of the channel at 16°S , subsequent to strong poleward currents. Furthermore, it has been suggested that their formation is associated with barotropic instabilities of the South Equatorial Current north of the channel, and the subsequent shedding of an eddy is due to the geometry of the narrows.

In this study an eddy resolving Hybrid Coordinate Ocean Model with $1/10^{\text{th}}$ of a degree resolution was used in combination with

geostrophic currents derived from satellite altimeter data to analyse vorticity entering the Mozambique Channel from the north.

The focus of this study was to analyse vorticity entering the MZC from the north, relating this to the variability observed in the SEC north of Madagascar and to show how it may contribute toward eddy formation in the channel. In so doing, it was shown that eddy formation in the MZC is related to variability of the SEC north of Madagascar and the increasing magnitudes of f and ζ , during the southward propagation of the

positive vorticity anomaly. A composite analysis from the model output (Figure 3) indicates that eddies form in the channel approximately 20 weeks following a vorticity anomaly north of Madagascar associated with a strong westward transport pulse in the SEC. Also, a seasonal signal occurs in the channel and evolves downstream, accounting for the seasonal changes in the eddy activity previously noted.

A connection between the large-scale variability of the Indian Ocean and Mozambique Channel eddies is significant, because it implies a downstream connection to the Agulhas leakage, which is the main pathway through which warm, saline water, critical for maintaining the meridional overturning circulation, enters the South Atlantic Ocean. Thus inter-annual modes of variability such as the El Nino Southern Oscillation and the Indian Ocean Dipole may influence the thermohaline circulation and hence global climate in a different way to what is presently known.

DYNAMICS OF THE BENGUELA CURRENT SYSTEM

JENNIFER VEITCH AND
FRANK SHILLINGTON

The Benguela system is unique among the three other major eastern boundary upwelling systems of the world's oceans in that both its northern and southern boundaries are dynamically linked to warm water current regimes, namely the Angola Current in the north and the western boundary Agulhas Current in the south. The northern and southern regions of the Benguela system are therefore both subject to influence from the tropical Atlantic and Indian Oceans respectively. Low oxygen water (LOW), originating in the tropical Atlantic episodically advects far south into the northern Benguela upwelling regime and often has catastrophic implications for the living marine resources there. In the south, the interaction of the north-westward path of Agulhas eddies with the upwelling front has been implicated in offshore advective losses of fish larvae. Also unique to the Benguela upwelling regime is the juxtaposition

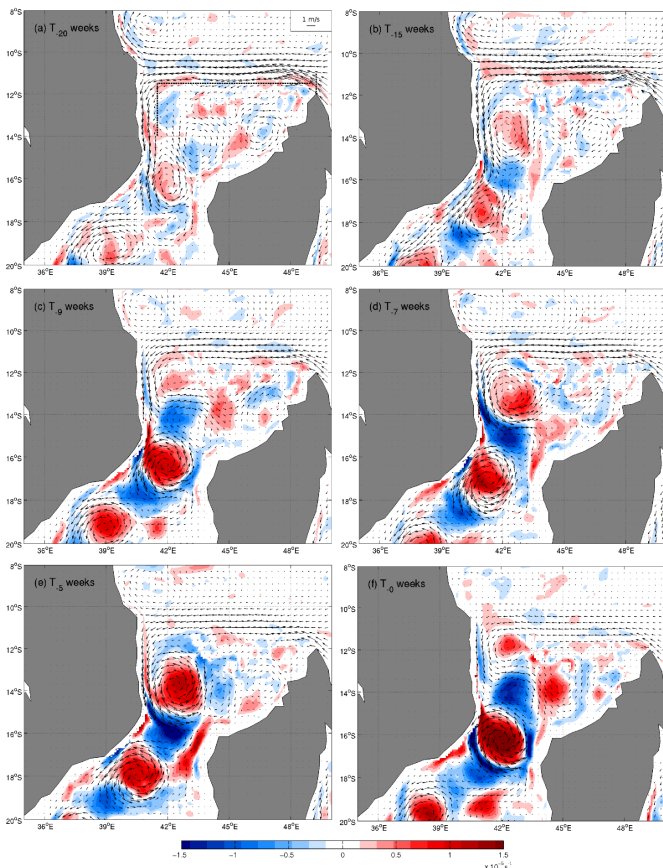


Figure 3: HYCOM vorticity (s^{-1}) and current (m.s^{-1}) composites for vorticity events in the narrows higher than the 95th percentile (T_0 ; f). Composite maps of 20, 15, 9, 7 and 5 weeks before the events are included as (a) T_{-20} , (b) T_{-15} , (c) T_{-9} , (d) T_{-7} , and (e) T_{-5} . The figure illustrates how a Mozambique Channel eddy is formed at 16°S following vorticity anomaly forming north of Madagascar and propagating into the channel.

of very low variability on the shelf with very high variability further offshore, particularly in the southern Benguela system where the offshore region has come to be known as the 'Cape Cauldron' due to its turbulent nature. Separating the northern and southern Benguela regions is the so-called 'LUCORC' (Lüderitz Upwelling Cell Orange River Cone) barrier that has been described as separating the system based on their different biological and physical characteristics. The LUCORC barrier is commensurate with the Lüderitz upwelling cell, that is often cited as the most vigorous upwelling cell in the world and is certainly the most vigorous in the Benguela upwelling system.

The objective of this research is to take a comparative approach in systematically investigating the disparate dynamics of the northern and southern Benguela regimes and the nature of the division between them (see Figure 4). The focus is on the equilibrium dynamics, so that the understanding of the mean state and seasonal cycle (which is dominant in the south Atlantic) may be improved, and the 'bench-mark' from which we measure extreme events might be clarified. The importance of intrinsic, meso-scale

variability in the system is addressed in a general way and more specifically, the role of Agulhas influx (and mesoscale features associated with it) in the Benguela system is investigated.

In order to study the northern and southern regimes in this systematic way, a modelling approach is employed in order to obtain spatially and temporally coherent output data.. Until now, modelling in the Benguela has been limited to semi-analytical solutions, fairly coarse resolution numerical simulations or to only the southern part of the system. The model simulation developed for this doctoral research is of sufficiently high resolution in order to capture the important mesoscale features of the system. It encompasses the Benguela system in its entirety, including the coastal upwelling regime as well as the large-scale circulation features further offshore. The Regional Ocean Modelling System (ROMS) is used to systematically investigate equilibrium conditions and seasonal variations of the Benguela system, including both the large-scale flow regime as well as the coastal upwelling regime. Results indicate that a shelf-edge poleward flow exists in the northern Benguela region which is driven primarily by the wind-stress curl via the Sverdrup relation. This is strongly seasonal and is most intense during austral spring and summer when the wind-stress curl is most negative. The poleward flow deepens as it moves southward and between $\sim 25\text{--}27^\circ\text{S}$ much of it veers offshore due to the nature of the wind stress curl. In the mean state, the Benguela Current is characterized by two streams: the more inshore stream is topographically controlled and follows the shelf-edge. The offshore stream is driven by nonlinear interactions of passing Agulhas rings and eddies from the south and does not have a striking seasonal signal.

enhanced in the Cape Peninsula upwelling cell due to geostrophic divergence (i.e. the offshore veering of the intense Good Hope jet). Therefore, upwelling rates based on the Bakun upwelling index, which takes into account only the intensity of the alongshore wind stress, need to be used with caution. The effect of topography on coastal upwelling was investigated by smoothing the alongshore coastline and topography variations in the model, which showed that in all of the seven major upwelling cells, upwelling is enhanced on the downstream side of capes. Mesoscale variability of the Benguela system is dominated by Agulhas influx and instabilities associated with it. In contrast with the high offshore variability, the broad shelf of the southern Benguela contains a region of low variability and is relative quiescent (Figure 4). The role of Agulhas influx on the Benguela system is explicitly investigated by creating an upstream "dam" in the model that induces an early easterly diversion of the Agulhas Current so that it does not enter the Benguela system. We are thus able to identify regions of local generation of instabilities, such as in the central Benguela region, where large filaments are generated, with or without Agulhas influence. The Good Hope Jet is shown to be enhanced, but not entirely generated by Agulhas influx and the fact that the offshore extent of the upwelling front in the southern Benguela tends to be limited by the shelf-edge is not related to Agulhas influx. This research has been specifically limited to equilibrium conditions in order to improve our understanding of the mean state and seasonal cycle of the Benguela Current system. Future modeling will investigate intra-seasonal, annual and inter annual variability.

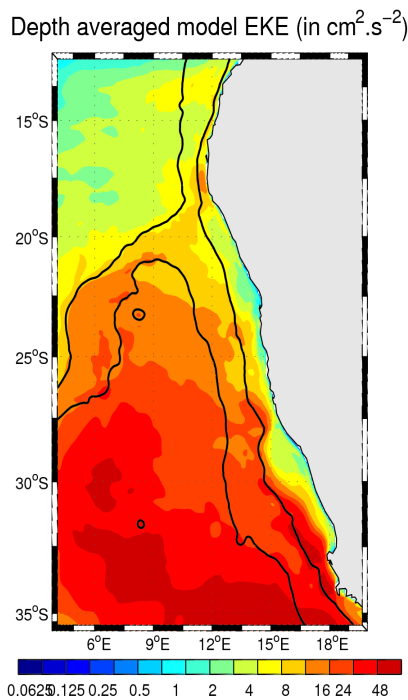


Figure 4: Depth averaged model-derived eddy kinetic energy (EKE – $\text{cm}^2.\text{s}^2$), which is used as a measure of mesoscale variability, of the Benguela System.

The model simulates all seven of the major upwelling cells within its domain. Our results show that upwelling rates in the northern Benguela are inhibited by the convergence of geostrophic flow at the coast, while upwelling is

SIMULATING AND FORECASTING SOUTHERN AFRICA'S OCEAN

JENNIFER VEITCH,
BJORN BACKEBERG AND
ROY VAN BALLEGOOYEN

Numerical ocean models can sometimes allow us to 'sample' a model ocean at a much higher space and time frequency than is possible by either satellite or *in situ* monitoring programs in the real ocean. With the advent of satellite observations in the 1960s, and the continual advancement of satellite technology since then, great insight into large-scale features and dynamics of the global ocean has been achieved. Unfortunately, most satellite sensors do not 'see' deeper than the surface ocean. *In situ* monitoring is a most important aspect of gaining ocean information, however it is also extremely expensive. Given the remarkable improvement in computing power and efficiency over the last couple of decades, high resolution ocean models can be run quite affordably and become a critical source of information.

Over the last decade, ocean modelling capacity has developed significantly in southern Africa. SimOcean is a multi-institutional initiative, including the Department of Oceanography at the University of Cape Town, the African Centre for Climate and Earth System Science hosted at the Council for Scientific and Industrial Research, and the Nansen-Tutu Centre, whose aim is to establish a unified southern African ocean modelling working group. It is an arena in which local capacity and expertise in numerical ocean modelling, analyses and operational forecasting can be shared and developed. More information on the SimOcean initiative can be found at www.simocean.org.za.

While the full scope of the SimOcean will be to augment and develop numerical modelling capacity in southern Africa in general, both in research and operational capacities, the initial goal will be to set up an operational oceanographic system that delivers regular and consistent

nowcasts and forecasts of the state of the ocean. These are of key interest for the following purposes:

(i) Marine safety: to improve the predictability of extreme events, such as cut off lows and mesoscale convective systems in the atmosphere; to monitor and predict the pathways and spreading of various tracers including toxic contaminants such as oil spills in the ocean; to support search and rescue of people and goods lost at sea.

(ii) Marine and coastal environment: to provide rapid environmental assessment in order to monitor and mitigate against the effects of, for example, harmful algal bloom (HAB) and low oxygen water (LOW) events as well as large-scale, climate related changes in the oceans surrounding southern Africa.

(iii) Marine resources: to provide support information for the offshore oil and gas industries, fisheries management and ecosystem characterization; to condition biogeochemical modelling of ocean primary productivity.

The operational initiative of SimOcean follows a 2-phased approach. The first phase (0-2 years) will use resources that are currently available in order to produce a marine forecast product and will serve as a demonstration, or 'proof of concept' project. It will downscale global ocean forecast products to higher resolution regional and limited area southern African domains and use global atmospheric forecast

products as forcing. As part of an assessment of the ocean model, a hindcast simulation will be run from as far back as the chosen wind forcing product exists (for example, NCEP from 1948-, QuikSCAT: 1999-2009 and ECMWF: 1989-2010). The

second phase (2-5 years) will focus on system enhancements and improvements of the forecast system, the emphasis being on research and development. Improvements to the implementation and demonstration phase will include data assimilation, ocean-atmospheric coupling, wave coupling. The potential for additional enhancements is enormous and provides huge scope for interdisciplinary and multi-institutional collaboration.

The SimOcean operational initiative forms the modelling pillar of the recently formed OceanSAfrica operational oceanography program that depends equally on the *in situ* observation, remote sensing and data dissemination pillars (see Figure 5). The vision of OceanSAfrica is to, through a combination of modelling and observations, deliver regular and systematic information on the state of the ocean that is of known quality and accuracy on open ocean to shelf-scales. In order to reach these objectives, the 4 pillars of OceanSAfrica need to closely coordinate their activities. Communication with users should be maintained throughout the planning, implementation, pre-operational and operational phases. Their feedback on the usefulness of the disseminated products is essential for validating the system and ensuring the sustainability of the system. Potential users include offshore industries, the navy, marine biologists, ecosystem modellers, marine resource managers, marine

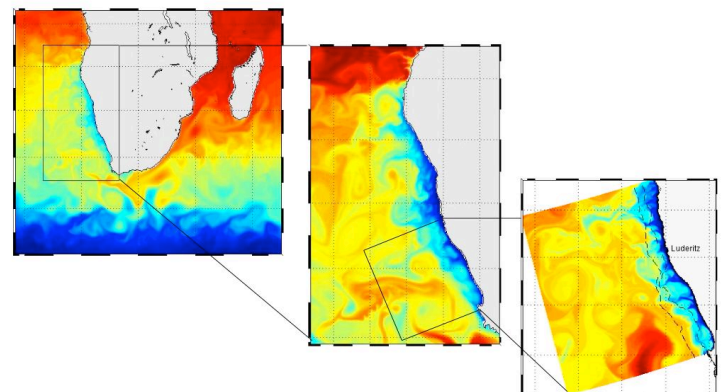


Figure 5: A series of 'nested' ROMS (Regional Ocean Modelling System) modelled sea surface temperatures (red = warm, blue = cold), increasing in resolution from ~27 km (on the far left) to ~3km (on the far right). The higher resolution models obtain their boundary conditions from the lower resolution, larger domain simulations.

leisure activities.

While the initial goal of SimOcean is the implementation of an operational ocean modelling system for southern Africa, intrinsic to the developmental process is the scope for research activities. For example, the archived data from the operational system as well as hindcast simulations could prove instrumental in contributing toward building an extensive oceanographic data-base that could support several research projects including the characterization and study of climate variability (change) in southern Africa. Alternatively, specific problems or features identified in the ocean forecast system can be addressed in separate model simulations that require a more idealized and process-based modelling approach. The expertise that will develop from, and be attracted by, the operational modelling initiative will naturally increase local modelling capacity.

Locally, the importance of southern Africa oceans lies in its high productivity, particularly associated with the Benguela upwelling ecosystem on its west coast that sustains a successful fishing industry and supports local communities. On global and climate scales the leakage of the Agulhas Current into the Atlantic Ocean forms a key component of the global thermohaline circulation. The fact that southern Africa borders both a locally important eastern boundary upwelling ecosystem and a globally significant highly dynamic western boundary current system presents a unique natural laboratory, in terms of both ocean dynamics as well as biodiversity. As southern Africans, we are perfectly positioned to take advantage of the scientifically bountiful ocean at our shores. Coupled with the potential for invaluable observational activities, an ocean modelling working group would identify southern Africa as a center of excellence in marine science with the potential to contribute significantly to global climate science.

DEVELOPING NEW AFRICAN OPERATIONAL REMOTE SENSING CAPABILITIES IN COLLABORATION WITH THE MARINE REMOTE SENSING UNIT AT THE COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

STEWART BERNARD, MARJOLAINE ROUAULT, CHRISTO WHITTLE AND ANDY RABAGLIATI

Nansen-Tutu Centre Earth Observation activities have been conducted through the Marine Remote Sensing Unit. The MRSU is a multi-institutional collective that has been mandated to serve southern Africa's marine earth observation needs, and uses expertise and infrastructure from the University of Cape Town (UCT), the Council for Scientific and Industrial Research (CSIR), the Department of Environmental Affairs (DEA), the South African Environmental Observation Network (SAEON), and the Centre for High Performance Computing (CHPC).

In response to the new South African Operational Oceanography initiatives such as OceanSAfrica and FP7 activities such as the Europe

Africa Marine Network (EAMNet), the MRSU has rebuilt its earth observation processing capability using the new Sun cluster based at the CHPC. The new cluster, rated at 27 teraFLOPS, is amongst the fastest 500 supercomputers in the world and is a national research facility funded by the South African Department of Science and Technology. The MRSU have ported and optimised their processing codes, based primarily on NASA's SeaDAS software and open source Python, to the new Sun facility. This will result in new and more robust processing capabilities: routine production of standard MODIS and MERIS data for Africa; the ability to provide new products to the African area by processing from Level 1 data; the ability to run new regional and experimental algorithms; the ability to handle large areas of MERIS Full Resolution data; and the ability to quickly provide regional data from the new MODIS global reprocess and recently released MERIS global reprocess. The new capability should provide significantly greater access to marine earth observation data for all African users, particularly given the development of a new marine

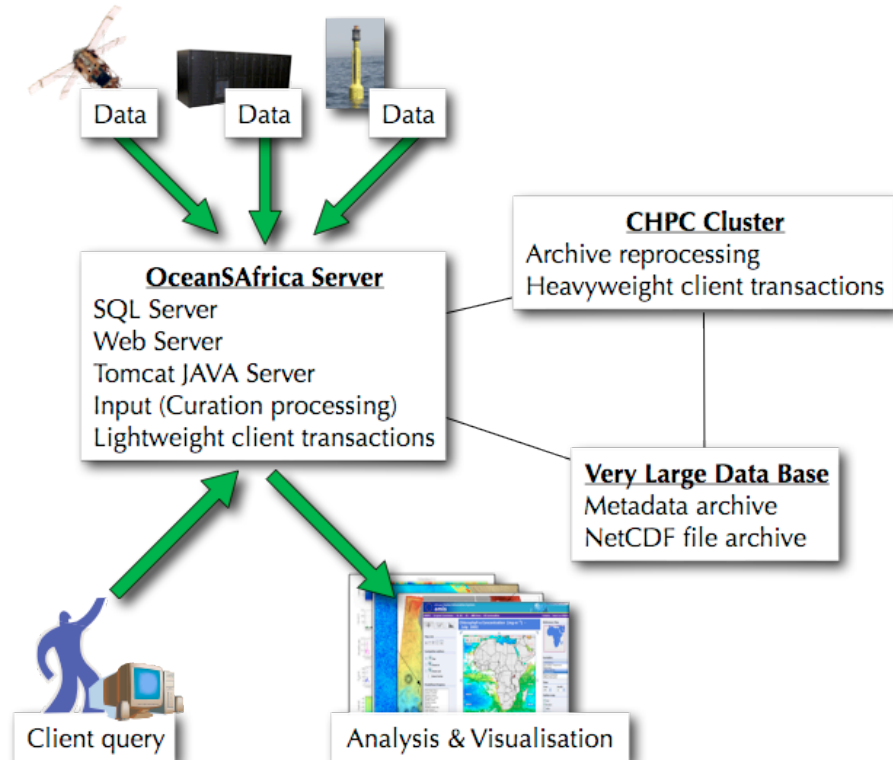


Figure 6. Schematic of the transactional structure of the OceanSAfrica Marine Information System as a component of the VLDB.

information system as a component of OceanSAfrica

This marine information system (see Figure 6), driven initially by earth observation needs, will provide OceanSAfrica with a highly visible and powerful marine information system capable of meeting users needs, and handling large volumes of disparate geo-spatial data & products. The development vehicle for this information system is the Very Large Data Base (VLDB), part of South Africa's cyber-infrastructure initiative. In strong collaboration with SAEON and the CHPC, the development work involves server side processing and storage, e.g. Geoserver, a spatially-aware open-source database product, and client-side open source javascript products e.g. OpenLayers, that communicate using standard geospatial protocols like WMS (Web Mapping Service) and WFS (Web Feature Service). The software combination allows a browser to collect and display geospatial information from more than one server, presenting the user with overlaid datasets from various sources and making this available to other client programs such as Google Earth. The system will be coupled to a database that stores all

meta and meso-data - descriptive information acquisition, processing/products, cloud cover, and data ranges.

The MRSU is part of the European Space Agency's CoastColour project, which aims to realize the value of high spatial resolution (260 m) MERIS FR data in the coastal zone. MRSU personnel have taken part in the CoastColour Round Robin algorithm exercise, analyzing the performance of regionally developed empirical and semi-analytical algorithms. This will be presented third quarter 2011 at the CoastColour User Consultation Meeting in Lisbon by two UCT postgraduate students: Hayley Evers-King and Marie Smith.

Marjolaine Rouault has been developing a South African capability to utilize Synthetic Aperture Radar (SAR) data for studies of the greater Agulhas Current regime, in strong collaboration with NERSC and CLS in France. Surface current velocities derived from the Envisat's ASAR observations over the Agulhas Current were evaluated through comparisons with surface drifter data, altimetry and sea surface temperature observations (see

Figure 7). Inadequate wind corrections caused occasional bias in the ASAR range-directed velocities particularly at low radar incidence angles. Occasionally observed wind-induced outliers cause a bias in the estimated ASAR velocities but did not affect the ability of ASAR to systematically image regions of strong surface current flow and shear. Time-averaged maps of ASAR derived surface current velocity seemed able to accurately capture the position as well as the intensity of the Agulhas Current. The quasi-synoptic nature of ASAR acquisitions combined with the relatively high resolution of ASAR surface current velocities also made it attractive for studies of sub-mesoscale processes and western boundary current dynamics. The output of this research was presented at the SEASAR workshop in Frascati, Italy in January 2010 and have been published in the Journal of Geophysical Research-Oceans.

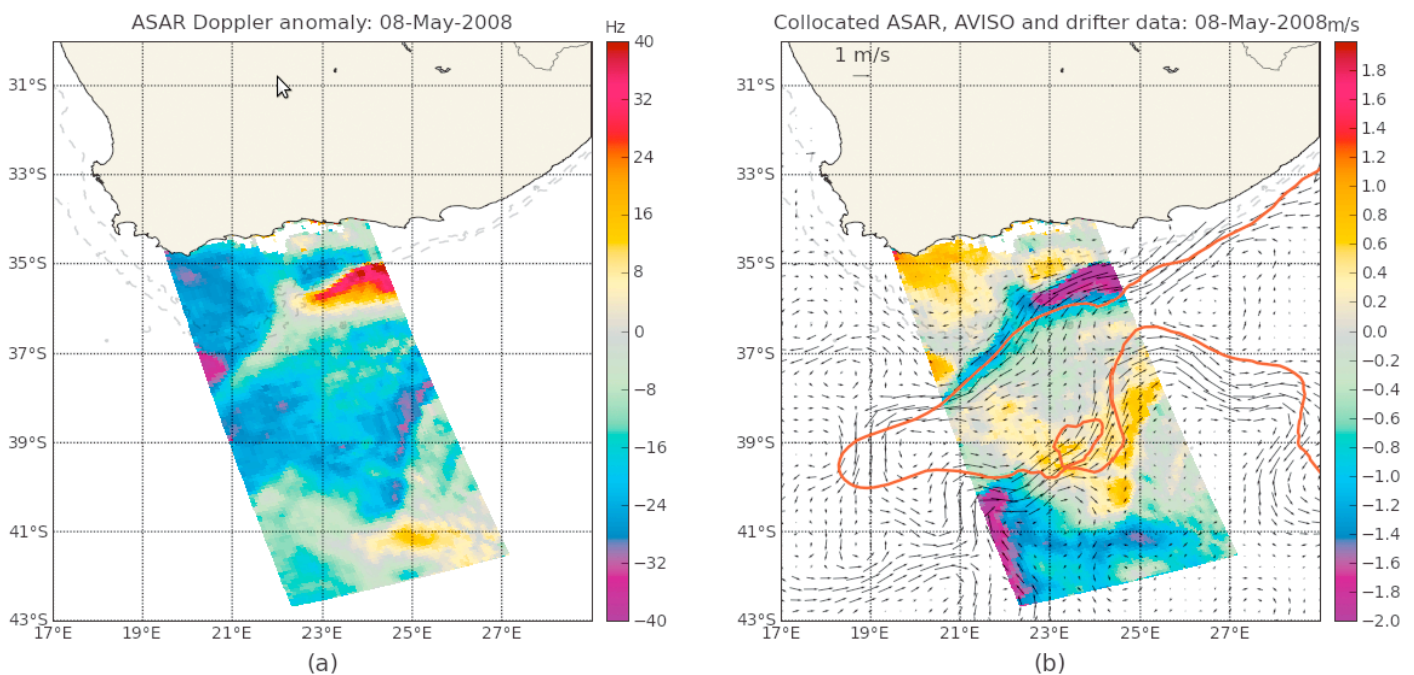


Figure 7: (a) Map of ASAR Doppler centroid anomaly (in Hz) corrected for large along-track cross-section variations and biases over land for 8 May 2008. (b) Resulting ASAR range-directed surface current velocity in m s^{-1} . Overlaid are vectors of geostrophic velocities derived by combining the CNES-CLS09 MDT with the AVISO NRT-MSLA product of that day. The trajectory of Lagrangian surface drifter 14926 between 9 June 2008 and 21 July 2008 is plotted as a red line. The stippled lines in Figures a and b indicate the positions of the 200 m and 100 m isobaths.

PUBLICATIONS

FROM MAY 2010

REFeree PAPERS IN INTERNATIONAL JOURNALS

OCEANOGRAPHY

Backeberg, B. C. and **C. J. C. Reason** (2010). A connection between the South Equatorial Current north of Madagascar and Mozambique Channel Eddies. *Geophys. Res. Lett.*, 37, L04604, doi:10.1029/2009GL041950.

Veitch, J., P. Penven and **F. Shillington** (2010): Modelling equilibrium dynamics of the Benguela Current system. *J. Phys. Oceanogr.* 40, 1942–1964.

CLIMATE RESEARCH

Rouault, M., B. Pohl and P. Penven, (2010) Coastal Oceanic climate change and variability from 1982 to 2009 around South Africa, *Afr. J. Mar. Sc.* 32(2): 237–246.

Pohl, B., N. Fauchereau, **C. J. C. Reason** and **M. Rouault** (2010). Relationships between the Antarctic Oscillation, the Madden–Julian Oscillation, and ENSO, and Consequences for Rainfall Analysis. *J. Climate*, **23**, 238–254.

REMOTE SENSING

Rouault, M. J., A. Mouche, F. Collard, **J. A. Johannessen**, and B. Chapron (2010), Mapping the Agulhas Current from space: An assessment of ASAR surface current velocities, *J. Geophys. Res.*, 115, C10026, doi:10.1029/2009JC006050.

REPORTS

Rouault M; Fauchereau N; Pohl B ; Penven P; Richard Y; **Reason CJC**; Pegram GGS; Phillippon N; Siedler G; Murgia A. (2010) Multidisciplinary analysis of hydroclimatic variability at the catchment scale 2010/05/25; *WRC Research Report No.1747-1-10*. Water Research Commission. ISBN: 9781770059559

CONFERENCE PROCEEDINGS

Backeberg, B., **J.A. Johannessen**, **M. Rouault**, and **J. Veitch** (2010). Preliminary inter-model comparison of the Agulhas Current with direct

range Doppler velocity estimates from Envisat's Advanced Synthetic Aperture Radar. ESA Living Planet Symposium, 28 June – 2 July 2010, *ESA's Publication Division (EPD), Special Publication SP-686*.

POPULAR SCIENCE ARTICLES

Veitch, J., **B. Backeberg** and **F. Shillington** (2010). SimOcean: modelling the ocean. *SANCOR Newsletter*, 191, 16-17, ISSN 03700-9026.

DOCTORAL DISSERTATIONS

Backeberg, B.: *Modelling the mesoscale variability in the greater Agulhas Current System using a Hybrid Coordinate Ocean Model*. Doctoral Thesis, Department of Oceanography, University of Cape Town, South Africa, 2010.

Veitch, J.: *Equilibrium dynamics of the Benguela system: a numerical modelling approach*. Doctoral Thesis, Department of Oceanography, University of Cape Town, South Africa, 2010.

STAFF IN 2010

SCIENTISTS

Bjorn Backeberg (100%) – Oceanography and modelling

Mathieu Rouault (50%) – Ocean-atmosphere interaction and climate

Frank Shillington (20%) – Oceanography and remote sensing

Johnny A. Johannessen (20%) – Oceanography and remote sensing

Chris Reason (10%) – Climate variability and modelling

Christo Whittle (seconded) – Oceanography and remote sensing

Jennifer Veitch (seconded) – Oceanography and modelling

Juliet Hermes (seconded) – Oceanography and modelling

Stewart Bernard (seconded) – Remote sensing and ocean optics

PHD STUDENTS

Christo Whittle (seconded) – Oceanography and remote sensing

Marjolaine Rouault (seconded) – Oceanography and remote sensing

Roy van Ballegooyen (seconded) – Oceanography and modelling

ADMINISTRATION AND TECHNICAL STAFF

Mr. Emlyn Balarin (seconded) – Finances

USEFUL LINKS

SimOcean: Simulating and forecasting southern Africa's ocean

<http://simocean.org.za>

OceanSAfrica

<http://cfoo.co.za/oceansafrica/>
(temporary development link)

Ocean modelling blog

<http://uctoceanmodelling.blogspot.com/>

Marine Remote Sensing Unit

<http://www.afro-sea.org.za/>



From the foundation ceremony of the **Nansen-Tutu Centre for Marine Environmental Research** in Cape Town in May 2010. First row from the left: Prof Berit Rokne, Achbishop Desmond Mpilo Tutu and Prof George Philander. Second row from the left: Ambassador Tor Chr. Hildan, Prof Johnny A. Johannessen, Prof Frank Shillington, Dr Neville Sweijd, Mr Hans Erstad, Prof John Field and Mr Lasse Pettersson.



Nansen-Tutu Centre for Marine Environmental Research

Cape Town, South Africa

<http://ma-re.uct.ac.za/nansen-tutu-centre/>

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